SOIL CONSERVATION

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Evaluating Our Practices on Demonstration Projects

By R. E. Uhland [1] and W. F. Peel [2]

1. Havoc caused by torrential rain of 7.1 inches where fields were not protected against run-off and erosion.

THE RAPID expansion of the work of the Soil Conservation Service throughout the United States naturally called for the use of many erosion control practices before they had been thoroughly tested under the varying conditions found on the many project areas. Our Service personnel have, from the very beginning, felt the urgent need for further study and evaluation of the effectiveness of our practices when applied in different parts of the United States. From the time the first demonstrations were started, general observations were made to determine whether or not the control measures were effective. As a result of these experiences, a number of practices and procedures were eliminated or materially altered. We refer particularly to the wide use of large and expensive structures and equipment which were found to be out of place on the average farm in that the proper use of vegetation proved more effective and economical.

Early in 1937, a systematic procedure was initiated by the research and operations divisions of the Soil Conservation Service, in cooperation with the State experiment stations, for evaluating the practices on the different project areas. The objectives of these evaluation studies were, first, to determine the effectiveness of different erosion-control practices or combination of practices; second, to provide facts to aid in improving these practices and in formulating plans for their extension; third, to delineate problems requiring research methods of solution and to present them to the proper research agencies for consideration; fourth, to assemble pertinent information for use

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2. Hundreds of tons of soil were carried on to highways. Expense for removal was heavy.

3. There was no erosion following a torrential 5-inch rain on strip-cropped fields supplied with grassed waterways.

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in connection with the preparation of project monographs; fifth, to further the dissemination of information on our soil conservation work in the field, particularly among cooperating agencies.

In order to ensure the proper planning for the conduct of evaluation surveys and field tests and thereby meet the above objectives, a standardized procedure was set forth in Field Memorandum SCS–553. This procedure called for the development of detailed working plans covering the evaluation of different erosion-control practices or, in some cases, phases of these practices. These plans set forth the objective of the study and give the detailed procedure to be followed in carrying out the studies.

The steering committee for each State assists in the development of these plans, particularly of the technical procedure. The plans are reviewed and approved by the members of this committee, which consists of the regional conservator or his representative, a designated representative of the division of research in the field, and the director of the State experiment station or his representative, before they are submitted to Washington for final approval. In the development of these plans, advice and assistance of the experiment station staff and the regional and project technicians are solicited.

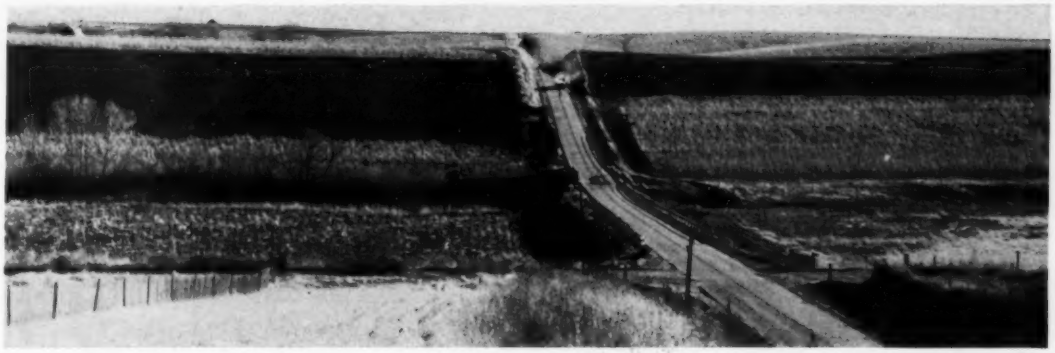
The evaluation surveys provide for the systematic recording, by the project technicians, of pertinent facts concerning these different erosion-control measures already installed on the farms. The procedure followed in evaluating our soil conservation practices on demonstration projects is divided into three stages, namely, (1) general observations; (2) detailed studies; and (3) field tests. The field observations made on practices already in use on the farm supply information of a general nature as to whether or not the soil and moisture conservation practices have been successful. More detailed studies must be resorted to, covering selected farms, to determine the factors contributing to the successes or failures. When these two procedures fail to give the necessary information, planned field tests are established under controlled conditions. This procedure makes it possible to give quantitative expressions to the relative effectiveness of varying practices and furnishes the information needed for their improvement. The initiation of field tests is delayed until their need has been definitely determined. These field tests furnish practical and effective demonstrations and make possible the collection of data so necessary for the improvement of field measures and practices for controlling erosion.

The procedure to be followed in analyzing, reporting, and publishing data on evaluation surveys and field tests was supplied in Field Memorandum SCS–727. Among other things, an annual report covering the findings from these studies is required at the end of each calendar year. In addition to this, however, special and timely coverage is to be given to critical storms, whether rain or wind. This makes it possible to make immediate use of these data and the annual report provides for the recording of any changes that are found necessary in the objective, methods, and procedures pertaining to the conduct of the work.

Timely observations of the effectiveness of vegetation in lessening erosion were recorded as a result of our surveys in California following the floods last spring. Studies in the Northwest, as well as in the Northeast, show the effectiveness of trash or straw left on the surface as a mulch in increasing water penetration and preventing both wind and water erosion. These studies are supplemented and substantiated by the cooperative research findings of the Service and the State experiment station at Lincoln, Nebr. Their preliminary findings show that the application, to the surface, of 2 tons of wheat straw per acre prevented any run-off, even though an inch and a half of artificial rain per hour was applied for 10 hours. Where no straw was added, or where the straw was incorporated with the soil, considerable run-off was recorded after the first hour. The same was true where basin listing was practiced. Water-penetration studies, where similar treatments were studied under normal rainfall, showed much deeper and more rapid penetration under the straw mulch than for any of the other treatments.

As a result of our experiences and studies in the northern Plains, ways and means are being developed for getting satisfactory stands of grasses economically. Contour furrows are proving quite effective in conserving water and providing a much denser cover of range grasses in both the Northern and Southern Great Plains.

An analysis of data secured on our project at Dadeville, Ala., following heavy rains in March and again in July, shows that, on the Cecil soils with slopes averaging 8 percent and having a good cover, the soil that was moved from the terrace interval into the terrace channel amounted to less than 4 tons per acre. With a medium cover, the moved soil was 14 tons per acre as compared to 54 tons of soil found in the terrace channel where the land was occupied by cotton or corn and farmed on the contour. Similar data from South Carolina show that the amount of soil moved into the terrace channel, where oats occupied one-half the terrace interval and corn or cotton the other half, was less than one-fourth that found where the



4. In the summer of 1938 a torrential rain fell on freshly worked soil. On the right hand side of the road terracing combined with strip cropping saved the fields. On the left hand side, serious gullying.

latter crops occupied the entire interval. It was found that close-growing vegetation greatly reduces the number of rills (indicating sheet erosion), the amount of soil deposited in the terrace channel, and the number of breaks in the terrace ridge.

A single rain totaling 7.1 inches was recorded on a portion of the Lancaster, Pa., project on June 27 and 28, 1938. Approximately 4.5 inches of this rain fell within an hour's time, and the maximum intensity reached 6 inches per hour for a 15-minute period. The havoc caused on cultivated land by this torrential rain is shown in photograph No. 1. Extremely heavy losses of soil, especially from unprotected slopes, resulted from this single rain. Bridges were washed out and highways seriously damaged (photographs 1 and 2). Photograph No. 3, on the other hand, shows that where fields were in sod crops or where they were strip-cropped with sod crops occupying alternate strips on the contour, very little damage resulted. At Ralston, Nebr., the effectiveness of terracing combined with strip cropping, as shown in photograph No. 4, was demonstrated when a torrential rain fell on freshly worked soil in the summer of 1938.

Results from the New York Experiment Station at Geneva, covering a very similar rain as to intensity and measuring 4.5 inches, which fell in 12 hours, illustrate the extreme losses to unprotected land when subjected to excessive rainfall. In round figures, it was found that on fallow land 66 percent of the total rainfall was lost as run-off which carried with it 46 tons of soil per acre. This was on a Dunkirk soil representing a slope of 5 percent. Corn, grown under the same conditions as to slope and type of soil and cultivated on the contour, allowed but 28-percent loss of rainfall as run-off accompanied by 8 tons of soil per acre. Likewise, red clover allowed a loss of only 5.5 percent of rainfall and 89 pounds of soil per acre, while the loss from land in grass was less than 1 percent with but 10 pounds of soil.

These examples represent only a few scattered illustrations of the type of information we are getting from these evaluation surveys and field tests. Our project areas serve as excellent laboratories, and there is every reason to believe that the information secured as a result of these studies will help in improving and extending our soil conservation program. The need for continuing this work and extending it to some of the newly established soil conservation districts is quite apparent. Since the proper use of land calls for the application of practices based upon the particular needs and adaptability of the different soils, it is necessary that we have information on the limitations of different soil conservation practices so that adaptations may be made to meet the special needs of the lands in different areas.

Construction work is practically completed on the installation of 20 small watershed run-off studies. Each of these watersheds is made up of several unit watersheds comprising different acreages, slopes, and vegetative cover. A variety of soil types and rainfall conditions is also included as a result of the wide distribution of the studies. Records of run-off can now be secured that will materially aid the engineer in estimating flood flow to be used in the design of conservation structures. Other technicians will also be interested in this information since water erosion is directly related to run-off, and a knowledge of run-off conditions and factors is essential for the best soil treatment and vegetative adaptation.

Contour tillage is fundamental to a sound erosion control program.

The complete orchard layout includes not only soil and water conservation and a water disposal system, but also such practical devices as orchard roads, etc.

Contour Planting and Terracing as a Basis for Soil and Water Conservation in Orchards

By John T. Bregger [1]

FRUIT growers as a class have been very careful about selecting favorable sites for their orchards and vineyards, at least from the standpoint of good soil and air drainage. This very situation, especially when accompanied by prolonged cultivation so common in the case of certain stone fruits, has brought about an excessive erosion problem. In fact, it constitutes the most serious erosion problem found in some agricultural areas today; it not only cuts yields and the productivity period of the existing plantings, but destroys the sites at least temporarily for the next orchards or field crops which might follow

The contour planting and terracing of vineyards—if not of orchards—is an Old World practice going back for several centuries in some locations. In America it is not clear just when the first contour planting of vineyards or orchards occurred. Undoubtedly there were numerous small plantings on or near the contour made by the early settlers from certain foreign countries where this practice had been in vogue. It was not until almost 1900, however, that any sizable acreage large enough to be called "commercial" was planted on terraces or "on contour."

Although no accurate survey has yet been made over the entire United States, the present area of contour fruit plantings is close to 40,000 acres. South Carolina alone accounts for about 15,000 acres of this total. By regions, the approximate 1938 acreages of contour orchards, in Soil Conservation Service demonstration areas alone are as follows:

	Acres
Region 1 (12 Northeastern States)	400
Region 2 (7 Southeastern States)	[1] 3,050
Region 3 (Michigan, Indiana, Ohio, Kentucky, Tennessee)	300
Region 4 (Arkansas, Louisiana, Texas)	[1] 1,500
Region 5 (Illinois, Iowa, Minnesota, Missouri, Wisconsin)	[1] 200
Regions 6 to 9 (Prairie and Rocky Mountain States)	75
Region 10 (California, Nevada)	[1] 13,200
Region 11 (Idaho, Oregon, Washington)	25
Total	18,750

[1] Project supervisor, division of research, Soil Conservation Service, Clemson, S. C.

[1] Not wholly confined to young orchards laid out by Soil Conservation Service technicians.

Because of the variation in rainfall, slope, soil, and other conditions in the different sections of the country, various types and systems of orchard terraces are in use at the present time.

First of all, terraces may be differentiated on the basis of grade. In general there are three types—level, diversion grade, and irrigation grade. The first type is invariably in use where complete conservation of rainfall is desired and will not be unduly dangerous. This may be the case in apple orchards where a permanent vegetative cover is maintained or in sections where semiarid conditions prevail. Level terraces are also adapted to short rows and where a well-drained or porous soil, with or without auxiliary protection, decreases the likelihood of over-topping under heavy rain.

The diversion grade terrace is the type most commonly used in the humid sections, particularly for cultivated orchards where the tree rows are rather long. Diversion grade terraces may vary from practically level to 1 percent in fall, depending upon length and soil factors. In most orchard areas these grades approach as nearly as possible the upper limit where scouring occurs. In the irrigation grade terrace, the use of which is almost entirely confined to California at the present time, the fall will run up to about 3 percent. Such terraces also serve as diversion terraces during the rainy season, at which time the presence of orchard cover crops slows up the rate of flow and usually prevents damage by scouring.

Diversion terraces have been occasionally installed in existing square-planted orchards largely as a makeshift practice to protect long slopes from the damaging effects of excessive and concentrated run-off. In addition to making the cultivation problem more complicated, this practice usually involves the removal or sacrifice of from 3 to 10 percent of the trees, but it has seemed more than justified on the basis of increasing the productive years of the orchard, as well as preserving the site for the next crop or orchard which will follow. In the English walnut orchards of western Oregon where the planting distance is much greater, the use of diversion terraces or ditches is often accomplished without sacrificing any trees whatever. Along this line it might be added that the use of temporary ditches (smaller and at closer intervals) is proving a very satisfactory method of preventing destructive erosion from the winter rainfall of that climatic area. These ditches after serving their purpose during the rainy season are cultivated out in the spring to be reconstructed the following fall about the same time the annual winter cover crop is sown.

From the standpoint of shape or cross-section, orchard or vineyard terraces may be characterized as bench, narrow-base, or broad-base types. The bench terrace is the normal type where the slope is above approximately 15 percent. On slopes less steep than that, terraces may be termed "narrow-base" or "broad-base," depending upon their width or cross-section. In general the narrow-base type (with a 4- to 6-foot ridge) is most common for orchard use, although the broad-base type is used occasionally where the spacing or interval approaches 100 feet as it does where only each fourth or fifth tree row is terraced. Such terraces may be as wide as 40 feet from the top of the back slope above the channel to the bottom of the down slope below the terrace ridge.

When it comes to the matter of terrace construction there are also some variations worthy of mention. In the first place, terraces have been constructed before as well as after the planting of the contour orchard. This difference has considerable significance as it determines to a large extent whether the trees will be planted on the terrace ridges or whether the ridges will be built slightly above the tree rows and gradually or more rapidly bury the tree roots on the uphill side. When large terraces are constructed prior to planting there may be a rather incomplete mixing of topsoil and subsoil which may or may not affect tree growth. When terraces are built in a gradual process as a result of contour cultivation following the planting of contour rows, the mixing of subsoil with topsoil and fertilizer elements in the form of artificial applications or turned-under cover crops, the resulting soil is invariably very desirable for tree root and top growth as well as for moisture infiltration and conservation. The so-called Reddick (California) bench terrace is constructed in this manner covering a period of about 10 years. Starting with the tree rows on little more than plow back-furrows, such terraces will be 6 feet above each other on some slopes by the end of the 10-year period when they usually reach a more or less permanent profile and size. The steep down-slopes or "risers" of such terraces are usually maintained in permanent vegetation.

Depending upon their size and span of construction, orchard terraces may be built with implements ranging from a disk harrow or plow to a 10-foot blade terracer. When a plow is used, the channel is often enlarged by following with a V-drag; this is also desirable to throw the loose soil nearer the tree row where the ridge will be less apt to be broken down by other orchard machinery. Terraces may be constructed from both sides as in the case of the Mangum or broad-base type, or

from the upper side only as with the Nichols terrace common in the Southeast.

More than one type of system has also been used in the contour planting and terracing of orchards or vineyards. For instance, a terrace may exist for each and every tree row, which at the beginning or in time, depending on its size, will catch all run-off from the row middle above it. This is invariably the case in a system of bench and level terraces which are usually all of the

Typical contour planted orange grove in Southern California. This is the ranch of "Ramona" in Helen Hunt Jackson's book of that name.

same size whether constructed prior to planting the orchard or allowed to develop over a period of years. In contrast to that, we find the use of so-called "master terraces," usually of the diversion type, which may be spaced at every second, third, or even fourth tree row, with the intervening rows, a portion of which may be point or spur rows, on the contour. In such an instance, however, these rows become "terraced" as a result of contour cultivation so that they hold all rainfall except in the heaviest rains when the excesss run-off is caught by the diversion terrace below.

Another variation in planting systems has to do with the lining up of rows in the opposite direction from those on the contour. These have been "staggered" in some plantings by merely planting at given tree intervals. In other orchards, however, the trees are kept in line up and down the slope to permit on gentle slopes an occasional cultivation to remove weeds or vegetative cover in the contour tree rows, or more commonly, for the sake of appearance. Better air drainage has also been advanced as a desirable feature of this method. Sometimes the contour rows change direction to the extent that it is impossible to line up in parallel all the rows in the other direction, in which case a radial system is employed. From the standpoint of planting distances, it is often recommended that the contour rows be spaced somewhat wider than in the square-planted orchard, but that the trees in the contour rows be placed correspondingly closer together.

Although contour orchard planting in conjunction with proper terracing ordinarily provides adequate erosion control, it is sound orchard practice to employ certain other practices in the orchard designed for soil building and fruit production. In this connection cover crops and mulching should be considered. When an orchard is newly planted, even the contour rows may not have ridges or terraces of sufficient capacity to check run-off fully. Here, a vegetative cover which might be the previous hay crop can be left in the contour tree-row middles as buffer strips; or if not already there, one can be planted. If the orchard is interplanted with a row crop such as strawberries or corn, the contour cultivation received by the intercrop will provide increased water storage, though these crops are not as desirable as a close-growing intercrop such as alfalfa. As the trees become larger and the root systems spread into the row middles, the cultivation which is gradually increasing the capacity of the terrace channel in each row also breaks up, year by year, a little of the inter-row cover crop, the final result being completely cultivated middles. When this stage is reached, a good annual cover-crop system will aid materially in preventing soil movement into the terrace channels, as well as in maintaining a porous soil to promote water absorption. In older orchards where shading interferes with a good cover-crop growth, mulching has proved a desirable substitute for orchard cover crops. Mulching of the terrace ridges has also been done to hold down weed growth and to aid in keeping ridges well stabilized at a desirable height to maintain sufficient channel capacity.

Although experimental data are yet rather limited regarding the more fundamental effects of contour cultivation and terraces on fruit plants and the soil, certain observations have been made which should be of interest. On the favorable side of the picture it has been definitely shown that soil and water conservation has been accomplished by terracing. It has also been noted that young trees in practically all locations make a superior growth when planted on terraces which are built largely of topsoil.

When an enlargement of the terrace takes place during a period of several years, the addition of a considerable layer of soil over the original tree roots has not proved harmful to the trees. Evidently the roots grow into this new soil layer and probably have an even greater feeding area than formerly. The terracing of existing orchards, where gullying was about to result in abandonment, has brought about an immediate stabilization of the orchard site, and has also materially prolonged the productive life of the trees. The economy of contour orchard operations might be mentioned as an additional advantage.

Terraces produced by contour cultivation when the orchard was young.

On the other hand, a few less desirable features in connection with contour planting have been observed here and there which should be mentioned. In some cases, these are the reactions of fruit growers who are utilizing this practice for the first time and who naturally find certain inconveniences they have not yet learned to cope with. One-way cultivation in itself is unpleasant to many fruit growers who have been taught that weeds or other vegetation left in the orchard during the cultivation period is nothing short of a disgrace. There is also the problem of spur rows, those short or point rows which, since they do not run the entire distance of the orchard, are particularly unhandy from the standpoint of spraying. A stationary spray system would solve this problem. Also in relation to spraying or dusting with the wind, there is the problem of a change in row direction when contour planting is done on certain sites. As a rule, however, most of the foregoing objections can be met by pointing out the lesser of two evils, and the practice which really saves the orchard or vineyard usually wins out.

Because of the far-reaching importance of the orchard and vineyard erosion problem and the widespread application of contour planting and terracing in meeting this problem, there is a real demand for some fundamental research along this line. For one thing, the moisture relationships of terraces of different sizes and profiles should be studied from the standpoint of where the trees should be planted, whether a cover crop will offer less competition under these conditions, etc. There may also be differences in fertilizer requirements, where all that is put on is conserved for the use of the trees. There should be some definite data on the effectiveness of contour planting and terracing in increasing fruit production (i. e., yields). Another problem for study is the effect of noncultivated terrace ridges or down slopes—whether in permanent vegetation or mulched—on the curculio and rodent problem.

Studies touching some of these problems are already underway. At the Hammondsport, N. Y., Soil and Water Conservation Experiment Station, a new contour- and bench-terraced vineyard has been planted on a steep slope where the soil moisture is being studied under mulched and unmulched ridges. In addition there are adjoining blocks of bearing vineyard, one planted and cultivated on the contour while the other is planted and cultivated up and down the slope, from which water run-off, soil loss, and production records have been taken for 3 years. A summary of these data, which show a decided advantage in favor of the contour block, is given in the accompanying table.

Effect of contour cultivation in New York vineyard, planted in 1910. Elvira variety, slope 25 percent. The plots were 225 feet by 48 feet. Yields, water and soil losses are computed on an acre basis [1]

Year	May to October rainfall	Up-and-down cultivation			Contour cultivation		
		Yield	H_2O loss	Soil loss	Yield	H_2O loss	Soil loss
	Inches	*Pounds*	*Inch*	*Pounds*	*Pounds*	*Inch*	*Pounds*
1935	27. 2	3, 748	.....	.....	5, 944	.....	.....
1936	12. 4	1, 044	0. 211	3, 093	2, 124	0. 029	72
1937	16. 4	3, 372	.054	176	7, 876	.011	10
1938	10. 0	2, 256	.....	.....	3, 464	.....	.....

[1] Preliminary Report, 1938. By Dr. John R. Lamb, Jr., project supervisor, Soil Conservation Experiment Station, Ithaca, N. Y.

(Continued on p. 263)

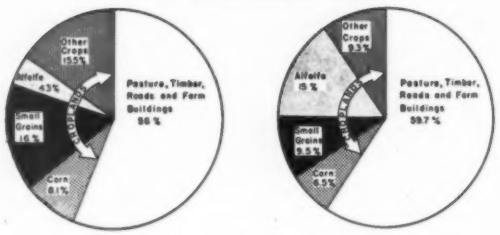
Coon Valley—4 Years After

By R. H. Musser [1]

IT WAS in the fall of 1933 that the Soil Conservation Service—then known as the Soil Erosion Service—began operations on this 92,000-acre watershed. At that time, Coon Valley was known as one of the most severely eroded agricultural areas in the Upper Mississippi region. Located in the heart of the unglaciated or so-called "Driftless Area" of southwestern Wisconsin and southeastern Minnesota—an area characterized by steeply sloping land and a highly erodible soil—Coon Valley showed the marks of years of exploitation. By cutting down much of the timber, permitting cattle to graze in the rest of it, and cultivating sloping fields

EROSION CONTROL PROGRAM CHANGES LAND USE ON COON VALLEY, WISCONSIN, FARMS

Survey of 374 Farms included in Soil Conservation Service Erosion Control Agreements affecting 38,303 acres of Land



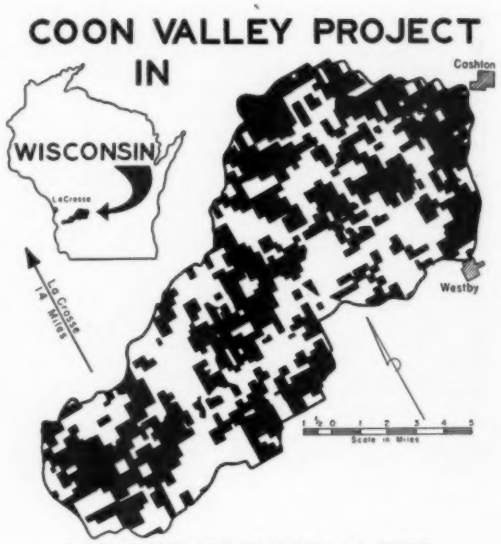
BEFORE CONTRACT
16,750 Acres of Croplands

AFTER CONTRACT
15,490 Acres of Croplands

in straight up-and-down hill rows, the white man had speeded up erosion processes tremendously. In many places huge gullies cut back through valuable cropland, and small shoestring gullies were to be found after a heavy rain in nearly every sloping field. Sheet erosion was everywhere evident.

Working in cooperation with the Wisconsin Experiment Station, the Extension Service, and individual farmers in the area, Soil Conservation Service officials began at once to set up a program of erosion-control demonstrations. On the land of farmers who had signed cooperative agreements with the Service, control programs including terracing, strip cropping, gully control by trees and dams, and woodland protection against grazing were established. Contour or around-the-hill farming replaced straight-row farming on the sloping land. Shifts in land use were made to give the maximum amount of protection to steep land: hay crops replaced clean-tilled crops on severe slopes, and such crops as corn were confined to the more nearly level land.

[1] Regional conservator, Soil Conservation Service, Milwaukee, Wis.



BLACK AREAS INDICATE FARMS ON WHICH EROSION CONTROL PROGRAMS HAVE BEEN ESTABLISHED

Today, it is clearly evident that the battle against the erosion menace is being won on the demonstration farms. Literally thousands of small shoestring gullies have been plowed in and completely healed as a result of terracing, contour strip cropping, and the other phases of the program. Dams and trees have effectively controlled larger gullies. Farmers in the area will tell you that erosion losses on controlled land are today but a fraction as great as they formerly were.

From the standpoint of farm management, the shift in land use has been the outstanding change brought about by the conservation program. A recent survey revealed that on 374 farms included in the demonstration program, the total acreage of cultivated land has been reduced from 16,750 to 15,490 acres, a reduction of 7.5 percent.

In the 1934 crop season, before the program had had a chance to go into effect, the 374 farmers raised 3,090 acres of corn. Last year they raised a little over 2,500 acres. In other words, they have reduced their corn acreage by approximately one-fifth. With regard to small grain, the acreage reduction has been even more drastic. In 1934, the cooperating farmers raised nearly 6,100 acres of grain. In 1937, they raised only 3,650. The acreage in small grain has been cut almost in half.

On the other hand, the acreage in hay crops has been considerably increased. With regard to alfalfa, the increase is especially striking. In 1934, a little over 1,640 acres of alfalfa were grown on cooperators' farms. In 1937, those same farms raised more than

Coon Valley farmers have fitted their field practices to the lay of the land. Curved farming is practiced in this curved country—to conserve soil and water. Contour strip cropping is common in the area.

5,780 acres of alfalfa. As a result of the erosion-control work, the alfalfa acreage has been increased over three and one-half times.

At first thought it might seem that, from the short-time point of view, farmers could not afford to reduce the acreages in cash crops as drastically as the Coon Valley farmers have done. Granted that the shift in crops was necessary for effective control of erosion, must it not, nevertheless, make a deep dent in the farm income?

The answer, as supplied by the farmers themselves, is that, far from working a hardship, the shift from cash crops to hay has been a lifesaver during the recent drought years. Alfalfa from Coon Valley was shipped out to farmers all over southwestern Wisconsin the year before last.

Coon Valley is in the heart of the dairy region, and in 1936 the farmers derived 66 percent of their income from dairying; hence, crop returns can be figured quite accurately in terms of nutrient production, and it is apparent that the erosion-control program has resulted in an actual increase in the amount of feed produced on the farms. The reduction made in corn and grain has been more than offset by the increase in alfalfa. The production of nutrients in the form of grain has been cut nearly in half; but in the form of roughage, nutrient production has been increased by more than 50 percent. In the beginning, the production of roughage was so much greater than the production of grain that the end result is a marked increase in total feed.

Approximately 23 million pounds of total digestible nutrients were produced on the farms each year before the erosion-control work was started. Last year, 28,157,000 pounds were produced, an increase of more than 5,150,000 pounds; however, the number of livestock on the farms has shown no corresponding increase. During the first 2 years of the program, there was only a 0.9-percent increase in the number of milk cows and only a 4.4-percent increase in young stock.

The butterfat production per cow, however, is on the increase on the 374 farms. In 1934, the average annual butterfat production was 166 pounds per cow. In 1935, the average was 190 pounds per cow. In 1936, the average was 207. In other words, the average production per cow has been increased by 41 pounds during the period between 1934 and 1936.

It seems safe to attribute this increase directly to the shift in crop acreage with its consequent increase in nutrient production and improvement in the quality of feed. Farm management specialists point out that a cow producing 208 pounds of butterfat a year requires 3,500 pounds of total digestible nutrients in addition to 168 pasture days. In Coon Valley, farms included in erosion-control agreements are much more likely to fill these requirements than farms operated in the usual way.

In the Northwest a 4,000-acre Oregon ranch profits to the extent of $1,200 for hunting privileges sold to a group of 20 sportsmen.

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Kudzu Plants by the Million

This valuable erosion-control plant is pictured on the front and back covers of this issue

FIELD operations in Region 2 have produced proof without end of the value of kudzu vines for erosion control, soil building, and forage production. This perennial legume, introduced from Japan, grows vigorously under favorable conditions; it roots at the nodes and produces a network that ties down steep gully banks, badly eroded fields, terrace outlet channels, and roadside banks and ditches. Kudzu hay is highly palatable and nutritious.

To supply plants for demonstration projects, camp work areas and soil conservation districts, the nurseries in Region 2 planted 3,926 pounds of seed in the spring of 1938. Early in the fall, definite plans were made for allotting, obligating, distributing and planting 12,000,000 seedlings—enough for 24,000 acres. The regional nursery report for February 1939 shows that 13,658,500 plants have been dug, an average of 3,479 plants per pound of seed.

The following extract from a joint report by J. N. Lowe, assistant regional agronomist, and John M. Downing, assistant regional engineer, shows how well the kudzu planting program has progressed in the northern half of Mississippi.

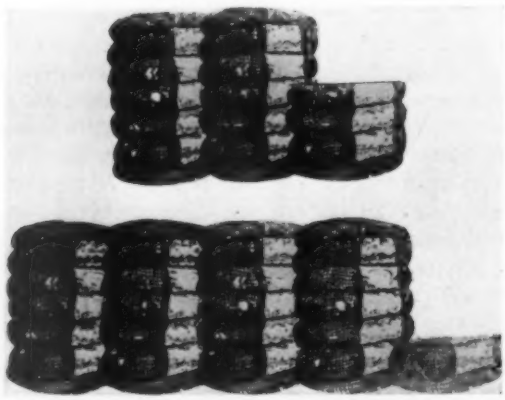
SUMMARY OF THE KUDZU PLANTING PROGRAM AS OF FEB. 16, 1939

Camp or project	Plants allotted to project	Obligated to cooperation	Received	Planted	Percent of land prepared
					Percent
New Albany	200,000	173,000	80,000	40,000	90
Coffeeville	200,000	179,400	99,500	74,500	75
Oxford	325,000	292,623	120,000	40,000	85
Senatobia	350,000	351,000	110,000	80,000	80
Ecru	250,000	219,670	74,000	74,000	90
Ashland	300,000	262,000	124,500	120,000	75
Lexington	300,000	293,494	174,604	115,493	85
Total	1,925,000	1,771,187	782,604	543,993	83

The Lexington, Senatobia, and Ashland camps have reported that they can use more plants if they are available.

Closed Level Terraces—No Run-off in 12 Years

By R. E. Dickson, B. C. Langley, and C. E. Fisher [1]



Total production of cotton per acre in 12 years (1927 to 1938): Upper, from land having rows with slope; lower, from land having closed level terraces.

TWELVE years ago, July 1926, a conference was held at Spur to develop plans for extending the soil and water conservation studies begun at the Texas Agricultural Experiment Station earlier in the year. In attendance were county and district agents of the region, representatives of the school of agriculture, the extension service and the experiment station of the A. & M. College of Texas, and H. H. Bennett, then of the Bureau of Chemistry and Soils, United States Department of Agriculture. Level terraces constructed on the station lands during the previous winter already had indicated that they were to be preferred over terraces with a slope. A suggestion from one of the group to close the ends of level terraces met with considerable good natured ridicule but it was finally agreed that it should be tried out as a purely experimental venture. The conference members decided on the location of the 20-acre experimental area, a piece of land mapped as Abilene clay loam with a slope of one-half of 1 percent. This much fall had frequently been given terraces in western Texas, and the prevailing opinion was that land so nearly level did not require terracing.

The area was divided into two experimental blocks. On one, closed level terraces with an effective height of 18 inches were constructed with vertical intervals of 12 inches between terraces. The other block was not terraced and the rows were run with the slope.

[1] Superintendent, agronomist, and assistant soil conservationist, respectively, of the Texas Agricultural Experiment Station, Spur, Tex. Since June 1936 these studies have been conducted cooperatively with the Soil Conservation Service.

These two blocks of land have been planted continuously to cotton during the 12-year period, 1927 to 1938.

No run-off has occurred from the area having closed level terraces and none of the crops have been damaged by too much rain. During this period a number of rains have been highly torrential and, also, the largest monthly rainfall in the history of the station, 11.13 inches, was recorded in September 1936.

The run-off from the unterraced area was determined with an Au-Fuzee water stage recorder operating over a stilling well adjacent to a stilling pond with a double V-notch weir at the lower end. It is generally conceded that this device gives highly accurate run-off measurements. The run-off results obtained over the 12-year period are presented in the accompanying table.

Run-off, yields, and market values of cotton from terraced and unterraced areas

Year	Rainfall	Run-off from land not terraced		Yield, lint per acre			Price per pound	Increased acre return
				From land not terraced	From land with closed level terraces	Increase		
	Inches	*Inches*	*Percent*	*Pounds*	*Pounds*	*Pounds*	*Cents*	
1927	16.12	0.38	2.36	239	279	40	22.75	$9.10
1928	19.99	2.88	14.41	58	217	159	16.63	26.44
1929	14.76	2.52	17.07	0	0	0	.....	0
1930	18.60	1.49	8.91	9	104	95	8.20	7.79
1931	16.46	.36	2.19	186	229	43	5.61	2.41
1932	27.70	2.83	10.22	0	0	0	.....	0
1933	15.59	.90	5.77	325	441	116	10.91	12.65
1934	12.88	.79	6.13	0	0	0	.....	0
1935	23.78	3.06	12.87	118	270	152	11.18	16.99
1936	24.37	3.98	16.33	39	55	16	8.39	1.34
1937	20.28	4.16	20.51	186	292	106	6.62	7.02
1938	19.24	3.24	16.84	147	236	89	8.42	7.49
Total	229.77	26.59	.....	1,307	2,123	816	.....	91.23
Average	19.15	2.22	11.57	109	177	68	10.97	7.60

The cotton crops in 1929 and 1932 were destroyed by hail, and a complete crop failure occurred in 1934, the second of two very dry years. During the years when crops were harvested, material increases in yields were obtained where all of the water was held, and in 1928, 1930, and 1935 the yields were more than doubled. The total increased yield for the 12-year period was 816 pounds of lint and 1,306 pounds of seed per acre. At an average price of 11.18 cents per pound for lint, and an estimated value of $20 a ton for seed, the increased value was $104.29. The increased cost of harvesting the larger crop, at 50 cents per hundredweight for snapping, was $16.12, and that of ginning at 30 cents per hundredweight was $9.79, or a total of $26.11. This leaves a balance of $78.18 an acre, which is the net return from holding all of the water on the land for a period of 12 years. The average annual return is $6.51 an acre, and this agrees with reports made by individuals using similar water conservation practices in this region.

Information is not available as to the amount of soil lost by erosion from the unterraced area, but experiments conducted under similar crop and slope conditions at this station show that with each inch of run-off 1.93 tons of soil are eroded. At this rate the soil lost from the unterraced area was 51.42 tons per acre during the 12-year period.

The practice of using all of the rainfall in cotton production gave such marked increase in yields that a further step in water utilization was undertaken in 1931. Flood water from 1,200 acres of rough land was diverted on to 120 acres of comparatively level land over which it was spread by means of level terraces with alternate ends partly open. This system of terraces is referred to as the "sirup-pan" system. The amount of water made available for crop production over a period of 8 years has been increased 19.5 percent above the natural rainfall. Cotton, comparatively sluggish in the use of water, has not been able to use this additional water as advantageously as some of the sorghum feed crops which have the ability to utilize large amounts.

This experiment has special value in that the results have been consistent over a relatively long period of years. During the 12-year period a number of torrential rains have occurred and also protracted rain periods of heavy rainfall without the loss, or even damage, of crops from excess moisture. It points definitely to the use of practices that will utilize the soil as a store place for water.

CONSERVATION IN ORCHARDS

(Continued from p. 259)

Another study relating to the moisture content at various locations in the terrace is being initiated by the Service in cooperation with the Pennsylvania State Experiment Station in southern Pennsylvania. Evaluation surveys on Soil Conservation Service operation projects in various parts of the country have also been set up to determine, as far as possible, effective size and interval of orchard terraces under various soil types and auxiliary erosion-control practices, and to evaluate several satisfactory and economical methods of building terraces in the orchard where the fruit grower is using ordinary farm or orchard machinery.

At Falcon, Colo., a rancher receives $120 a year for duck-shooting privileges and $75 a year for his half-share of the muskrats taken by a local trapper from four lakes on 640 acres.

Puerto Ricans Serve Conservation Program

WHEN, some two and a half years ago, Soil Conservation Service technicians began the development of a program in Puerto Rico, they found themselves faced with problems extraordinary. They must control erosion in a small mountainous country and at the same time tolerate and help to maintain a "slope agriculture" to provide subsistence for a dense population. Sugar centrals covered the rich valleys and the narrow coastal plains; food crops must be raised largely on the sides of steep mountains or in the foothills. Many of these slopes were badly eroded, and because of the dense population, and the surrounding ocean, a land-retirement program was out of the question. Erosion must be controlled inexpensively and the revegetative plants used must be principally food plants.

In the beginning it seemed that not the least of the problems was that having to do with the training of native Puerto Ricans to serve as agricultural agents and aides in setting up soil and water conservation practices. But G. L. Crawford, in charge of the work of the Service on the island, discovered, while preliminary research and operations were in progress, that students of the College of Agriculture of the University of Puerto Rico were interested in saving the soil of their mountainous tropical country and eager to learn the approved methods of the Federal Soil Conservation Service. Some of these men were already working with the farm program of the Puerto Rican Reconstruction Administration, and they were quick to see the need for soil conservation methods in their vocational agricultural program. The Reconstruction Administration then made it possible, by furnishing the necessary funds, for these technicians and students to work with members of the Service staff in surveys, research, and demonstrations. These native technicians, paid from funds supplied by the Reconstruction Administration, are now working on soil and water conservation problems in cooperation with the Service, and they are attacking the various phases of the program with extraordinary enthusiasm for the details of the practices adaptable to the island.

Some months ago, to encourage these native Puerto Rican agents and aides, Mr. Crawford arranged a competition for articles written by them, in English, on any soil conservation subject. Nineteen articles were prepared and sent to Washington to be read and judged by the officials concerned. The judging was difficult, as all the papers were well done. First place went to Joaquín Oliver, for his article on the soil erosion control work at La Plata Farm in the Cayey area. He presents an excellent and detailed picture of soil conservation demonstrations in an old tobacco region of the tropical country. Ovidio Garcia Molinari's observations on Possible Erosion Control Grasses of Puerto Rico was judged second-best of the 19 articles. He gives a careful account of the methods of study and the grasses investigated at the Soil Conservation Service research plots at Rio Piedras. Third place was won by Samuel Gracia, soil surveyor, for his paper, Soils, Soil Conditions, and Their Relation to Erosion Control Practices in the Cayey Area.

These three articles are presented in part on the following pages. They tell, better than could be told in any other way, the story of the work of the Soil Conservation Service during recent years in Puerto Rico.—PHOEBE O'NEALL FARIS.

General view of Soil Conservation Service practices over La Plata Valley and La Plata Hill, Cayey area, Puerto Rico.

I

Soil Erosion and its Control at La Plata, Cayey Area

By Joaquín Oliver

LA PLATA farm was first cleared about 1889. The first to plant tobacco in this section were the Rucabados and they continued the practice for 13 years. The Puerto Rican Reconstruction Administration bought the farm in 1935.

It consists of 721.15 cuerdas [0.97 acre] and is divided as follows: Central service farm 39.99 cuerdas; vocational school, 74.9821; tobacco institute, 10.5347; Insular rural school, 1.0385; roads, 8.6110; brooks, 0.8040; under cultivation, 172.87; idle land and pasture, 449.9593 cuerdas.

The Puerto Rican Reconstruction Administration has maintained the Central Service Farm and the rest of the cultivated land was divided into parcels and distributed to laborers, each parcel with concrete house and 5 to 9 cuerdas of land. The parcel owners pay a small rent for their house and land and it is supposed that in the near future they will pay for them under a 20-year payment plan; at the end of the 20 years they will have fulfilled their contracts and the parcels are automatically their own.

Rural life at La Plata has improved a great deal. Before 1898 workers earned about 37½ cents daily, and later the corporations paid their workers 50 to 60 cents a day. From 1935 on, their wages have increased to $1.50 a day. A farmer lives a better life with a good house and a piece of land on which to make his living.

The normal rainfall is about 55 inches, most of which falls in highly intensive rains from June to November. The rest of the year is almost dry. Topographically, La Plata Farm is a valley bounded

by mountains with undulating slopes with gradients from 25 to 75 percent.

Extending from the hills are colluvial slopes having less grade but the land is always more or less rolling with intermittent streams leading to the Rio Grande de La Plata which flows throughout the year * * *.

For many years this land has been subject to abuse and misuse. Improper cultural practices in tillage and cultivation have caused the loss of topsoil from large areas and a severe loss of other natural resources as well. There too has been a wastage of fertility by overcropping as a consequence of pioneer period of development and exploitation. Much of the best cropland is already seriously damaged. It was found that the limiting factor in the Cayey area was the lack of technical knowledge and that a sound soil conservation program would have to be established so that farmers chiefly dependent on crop production for their subsistence might learn conservation methods of crop production and soil fertility maintenance.

The Soil Conservation Service at La Plata has provided the necessary means and equipment to put into practice several demonstrations. The purpose was to control old practices that were leading to increased erosion and to establish modern and scientific soil-conserving and soil-building practices.

The work at La Plata began with a general survey of all parcels to collect local information regarding cultivation practices, kind of crops grown, etc. This was followed by an erosion and soil survey to determine the special needs of the individual farms and areas

Demonstrations on strip cropping, barrier strips, terracing, vegetative protection of outlet channels and ditches, hillside or diversion furrows, and crop rotation are now carried on in this section of the Cayey area. The objective is to discover which are the best practices to be recommended to farmers so that they can make better use of their land.

On those lands which have been in cultivation and where erosion is rather serious, strip cropping is on trial. Bands of close-growing crops are put on the contour, alternated with the regular row crops. The width of the strip is determined by the slope of the land and type of soil. The principle involved is that the bands or strips shorten the slope, reducing the speed of the running water and acting as a filter to the soil being carried out by the running water; also the strips serve as water spreaders and prevent the concentration of water in low places.

To observe what is the best to recommend, Soil Conservation is trying the following: (1) Strip cropping on the contour; (2) strip cropping with furrows of 0.8-foot fall per 100 feet at lower side of cultivated strip; (3) strip cropping with a cane-like grass planted on the upper part of the cultivated strips.

The importance of contour tillage in combination with strip cropping, as well as proper crop rotation in them, is specially emphasized and put into practice.

The possibility of forming a bench terrace with subsequent plowings to a cane-like barrier plant is another of the practices on trial at La Plata. To test their effectiveness for erosion control, several kinds of barrier strips are being demonstrated. Among them are:

(1) Barrier strips planted on a ridge resulting from the construction of a furrow of 0.8-foot fall per 100 feet;

(2) Barrier strips with a furrow of 0.8-foot fall per 100 feet, beneath the barrier plants;

(3) Barrier strips consisting of a 3-foot row of natural grass; and

(4) Barrier strips with barriers planted on the level (without a furrow).

The abilities of different barrier plants to withstand plowed dirt, as well as their stooling qualities, soil adaptations, and drought resistance, are also on trial. The plants being tested are milo maíz, dwarf milo maíz, white kafir, Sudan grass, Merker grass, Guatemala grass, elephant grass, pigeon peas, Crotalaria, and sweetclover.

Barrier strips are staked on moderate slopes which have sufficient soil for the formation of a bench terrace; and vertical spacings of 4 and 6 feet are being tried out.

On the Mabí soils where there is deep and approximately uniform level soil, and where the slope does not exceed 15 percent, terracing is the soil conservation practice used. These are no more than ridges of earth thrown up across the hillside, but in making the ridge a broad shallow channel is formed along its upper side through which the collected water flows at a very low velocity to the outlet channels.

The entire field can be cultivated by the farmers. For planting tobacco in this region Soil Conservation Service has suggested running the rows with a 2-percent grade between the terraces; for other crops the rows are run parallel to the terrace. The vertical distance or drop between terraces depends on the slope of this land and soil type.

Old natural water courses are reshaped and used as terrace outlet ditches. Bermuda sod strips are placed at 6 inches vertical spacing. The rapid growth of Bermuda grass and the manner in which the interlocking rootstocks and runners cover the whole sur-

face of the channels serve to prevent soil erosion and gully formation within them. Horquetilla grass is being tried in some of the ditches; it is very similar to Bermuda grass in stooling qualities.

As a substitute for the old diamond ditches on the tobacco lands, hillside or diversion furrows are being constructed. The different vertical spacings used are 6, 12, and 18 feet, with a fall of 0.8, 1, 1.5 feet per hundred feet, respectively. Diversion furrows with 6-foot vertical interval are 8 inches wide and 6 inches in height; those staked at 12 feet vertical interval are 10 inches wide and 8 inches in height, and those at 18 feet are 12 inches wide and 10 inches in height. All of them have a side slope of 1:1 and are not longer than 500 feet.

One of the objectives of the Soil Conservation Service in the work at La Plata is to give farmers an understanding of the value of crop rotation in maintaining soil productivity and soil improvement and to reduce erosion. A cropping program covering a period of 5 years is being worked for all parcels. Adaptations of crop to soils and the favorable sequence in maintaining fertility and physical conditions of the land are being closely observed.

Stabilizing a big gully at Rio Piedras.

II

Observations on Possible Erosion Control Grasses of Puerto Rico

By Ovidio Garcia Molinari

FROM all over the island different species of grasses have been collected and planted in small plots (one one-hundredth of an acre each) and placed under observation at the Soil Conservation Service research station at Rio Piedras. All those showing possibilities for use in any phase of soil and moisture conservation have been transferred to concentration plots to determine their values for use in protecting terrace outlet channels and terrace banks, for barriers, for controlling head erosion in gullies, for gully slope stabilization, for road banks, levees, and ditches, for controlling sheet erosion, and for pasture revegetation.

During the observation period, all possible data are being obtained relative to the characteristics and methods of handling the grass, as well as its adaptability to particular environments and uses. Notes are also taken on all species of grasses under observation regarding the following: Longevity; height; habitat; habit of growth; propagation; resistance to diseases, insects, droughts, excessive moisture; root system; clump or sod forming characteristics; growth rate; soil and moisture conservation properties, including soil-binding capacity, moisture-conserving and humus-forming properties, soil protective cover,

adaptation to a wide range of soil and climatic conditions, procumbent growth habit for prevention of sand blowing as well as sheet erosion. The grasses are studied also from the standpoint of their economic values—for forage, for industrial uses, or for sundry uses such as lattices and farm constructions or ornamental purposes.

All available facts are obtained regarding common farm practices, such as proper rate and depth of seeding, time of planting, methods of planting, blooming time, time elapsed between blossoming and shattering of mature seeds, after-ripening period, and cultural practices necessary for ultimate, successful establishment in demonstration projects and on farm lands.

The recommendations suggested in this paper regarding the use of some of the most promising native grasses for erosion control, are based on personal observations during 5 months of work in the Soil Conservation Service. After further experimentation has been done some of these suggestions and conclusions will undoubtedly be modified.

Grasses Suitable for Terrace Outlet Channels

The best grasses for use in outlet channels are those short-growing grasses, not over 12 inches in height, preferably only 4 to 6 inches tall, with fine stems and leaves that will be easily bent by the flowing water, with a dense, close-growing type of growth covering the entire surface of the ground.

Some of the grasses growing wild in Puerto Rico, and which show possibilities for terrace outlet protection are the following:

Bermuda grass, *Cynodon dactylon* (L.), Pers.—This is an excellent grass for outlet channel protection. It has a dense type of growth, short, fine stems and leaves easily bent by the flowing water, and widely creeping stolons producing roots at the nodes. It forms a thick mat not over 8 inches high and covers the entire surface of the ground. Its netted root system, several inches deep, extends in every direction. It can be successfully propagated either by seeding or vegetatively. It is a perennial, highly resistant to droughts, diseases, poor soil conditions, and hurricanes and is adapted to soil types having different physical and chemical conditions. Its great rapidity of establishment and its aggressiveness are important characteristics.

One point against this grass is its rootstock-forming habit which makes eradication from cultivated fields very difficult. It is not as desirable as many other grasses, due to its low palatability. It is, nevertheless, relished by livestock when they get accustomed to it, specially horses, mules, goats, rabbits, and chickens.

Centipede grass, *Eremochloa ophiuroides* (Munro), Hack.—This grass has been recently introduced from the United States. It is a creeping, stoloniferous grass, not over 5 inches tall, thus making an excellent cover for outlet channels. It forms a thick mat above the ground, and has a netted root system extending 6 to 8 inches vertically into the ground as well as laterally. It develops runners or stolons frequently, with more than 20 roots per linear foot of stolon. Its soil-binding ability is excellent. In general, it is as good for soil erosion control as Bermuda, having the advantage over the latter in that it does not produce rootstocks and therefore is not so difficult to eradicate.

One disadvantage of the Centipede is that the percentage of seed germination is relatively low so that it has to be propagated vegetatively and during a favorable rainy season.

Knotgrass, *Paspalum distichum*, L.—This grass is now being tried for use in erosion control in Puerto Rico. According to observations thus far, it appears to be well adapted for use in outlet channel protection as well as for ditches, terrace banks, and gully bank stabilization.

Its resistance to prolonged droughts, its adaptability to poor soil conditions as well as its ability to thrive in wet soils cannot be surpassed by many other short-growing grasses. It grows as rapidly as, if not more rapidly than the Centipede or Bermuda grass. It is a widely creeping grass, very stoloniferous with growth above the ground of 4 to 12 inches forming a mat-like coverage. It can be propagated vegetatively as well as by seeds. It does not produce rootstocks and is relished by livestock. It can be planted at any season of the year.

Java grass, *Polytrias amaura*.—This grass is not as stoloniferous as the Centipede, Bermuda, or *Paspalum distichum*. It forms a very thick covering on the surface. It is a short grass, not over 6 inches tall, with very fine leaves and stems that can be easliy bent by flowing water.

This grass undoubtedly has possibilities for use in ditches and outlet channels as well as for diversion channels and terrace banks.

A point against it is that it seems to be attacked by the chinch bug, *Blissus leucopterus*, in the western part of the island, although in the northern and eastern parts it does not show any injury from this insect.

Grasses Suitable for Barriers

Several species of grasses have been tested for barrier use in Puerto Rico. Those listed below have been under observation for some time and because they are

long-lived (perennial), have deep, penetrating, extensive root systems and comparatively thick, erect stems, strong stooling habits, and are useful for forage or for industrial purposes, it is thought that they will respond to barrier requirements.

Elephant grass, *Pennisetum purpureum*, Schum.
Guatemala grass, *Tripsacum laxum*, Nash.
Merker grass, *Pennisetum purpureum* var. Merkeri.
Japanese cane, *Saccharum officinarum*, L.
Wild cane, *Gynerium sagittatum* (Aubl.), Beauv.
Indian cane, *Phragmites communis*, Trin.
Equatorian grass, *Pennisetum occidentale*.
Jobs-tears, *Coix lacryma—jobi*, L.

Grasses Suitable for Terrace Banks

Grasses for this use should be perennials producing extensive netted root systems and having decumbent growth and an abundance of roots coming from nodes (stoloniferous). Their growth should be rapid and they should form a thick covering of the entire bank surface. In addition, they should have value as forage or pasture.

Such native grasses in Puerto Rico are the following:

Sour grama, *Paspalum conjugatum*, Bergius.
Centipede grass, *Eremochloa ophiuroides* (Munro), Hack.
Knotgrass, *Paspalum distichum*, L.
St. Augustine, *Stenotaphrum secundatum* (Walt.), Kuntze.
Carpet grass, *Axonopus compressus* (Swartz), Beauv.
Bermuda grass, *Cynodon dactylon* (L.), Pers.
Java grass, *Polytrias amaura*.
Malojilla, *Eriochloa polystachya*, H. B. K.
Molasses, *Melinis minutiflora*, Beauv.
Straw grass, *Andropogon annulatus*, Forsk.

Grasses Suitable for Controlling Erosion at the Heads of Gullies

Grasses for this purpose should possess, among others, the following characteristics: (1) A deep extensively netted root system; (2) stout stems (culms) with sufficient strength to support great forces; (3) strong stooling habits; (4) long-life (perennial); and (5) abundance of above-ground growth or foliage. Some of the most outstanding native grasses in Puerto Rico for such a purpose are:

Bamboo, *Bambusa bulgaris*, Schrad.
Pito, *Lasiacis divaricata* (L.), Hitchc.
Wild cane, *Gynerium sagittatum* (Aubl.), Beauv.
Caña India, *Arundo donax*, L.
Common reed, *Phragmites communis*, Trin.
Pachuli, *Vetiveria zizanioides* (L.), Nash.
Matojo blanco, *Paspalum virgatum*, L.
Gramalote, *Panicum maximum* Var., X.
Uba cane, *Saccharum officinarum*, L.
Guatemala, *Tripsacum laxum*, Nash.
Rattail, *Arundinella confinis* (Schult), Hitch. and Chase.
Sweetgrass, *Paspalum plicatulum*, Michx.

The following creeping stoloniferous grasses are to be used in combination with those mentioned above:

Molasses grass, *Melinis minutiflora*, Beauv.
Carpet grass, *Axonopus compressus* (Swartz), Beauv.
Knotgrass, *Paspalum distichum*, L.
Malojillo del monte, *Panicum laxum*, Swartz.
Carruzo, *Ichnanthus pallens* (Swartz), Munro.
Yerba de Madera, *Oplismenus hirtellus* (L.), Beauv.
Sour grama, *Paspalum conjugatum*, Bergius.
Pendejuelo, *Paspalum decumbens*, Swartz.
Straw grass, *Andropogon annulatus*, Forsk.
Palmilla, *Setaria palmifolia* (Willd.), Stapf.

Grasses Suitable for Use in Controlling Erosion on Gully Embankments

These grasses should possess a deep extensive root system, and should be preferably stoloniferous. They should form a thick growth above the ground capable of covering the entire surface of the bank and forming a layer of humus (decayed foliage), that will add to the organic content of the surface soil, and at the same time prevent the direct beating of raindrops against the bare soil and subsequent mud formation and soil washing. The grasses must have some economical value, either as forage or for industrial uses. Such grasses in Puerto Rico that are adapted for gully bank stabilization are:

Molasses, *Melinis minutiflora*, Beauv.
Melojilla, *Eriochloa polystachya*, H. B. K.
Knotgrass, *Paspalum distichum*, L.
Centipede, *Eremochloa ophiuroides* (Munro), Hack.
River grass, *Echinochloa polystachya* (H. B. K.), Hitchc.
Trompetilla, *Hymenachne amplexicaulis* (Rudge), Nees.
Aquatic grass, *Panicum aquaticum*, Poir.
Para grass, *Panicum purpurascens*, Raddi.
St. Augustine, *Stenotaphrum secundatum* (Walt.), Kuntze.
Melaillo, *Panicum glutinosum*, Swartz.

During the first year a quick grass covering is needed to prevent surface soil washing while the permanent vegetation becomes established. These quick growing native grasses promise to produce fairly good results:

Malojillo del monte, *Panicum laxum*, Swartz.
Carruzo, *Ichnanthus pallens* (Swartz), Munro.
Carrucillo, *Panicum trichanthum*, Nees.
Yerba de Madera, *Oplismenus hirtellus* (L.), Beauv.
Canutillo, *Lasiacis ruscifolia* (H. B. K.), Hitch.
Cerrillo, *Sporobolus indicus* (L.).
Straw grass, *Andropogon annulatus*, Forsk.
Yerba egipcia, *Dactyloctenium aegyptium* (L.), Richt.
Palmilla, *Setaria palmifolia* (Willd.), Stapf.

Echinochloa polystachya (H. B. K.), Hitch., *Hymenachne amplexicaulis* (Rudge) Nees, and *Panicum aquaticum* Poir., are grasses that normally grow on wet river banks, brooks, marshes, and shallow water, but they have been tested for growing under dry upland soil conditions, and have shown to adapt themselves to such dry-land conditions quite satisfactorily. They grow over 8 feet long, with culms spreading and producing roots at the nodes. They are therefore promising new grasses for erosion control, besides being relished by livestock.

Grasses Suitable for Controlling Erosion in Diversion Ditches, Levees, and Road Banks

Grasses adapted for use in diversion ditches should be of the fine growing type to retard the flow of water to a suitable minimum degree. These grasses should have a decumbent growth and be stoloniferous with extensively netted root system so as to prevent scouring by the water at the bottom and sides of the ditches.

Those grasses already mentioned for use in outlet channels and terrace banks can be successfully used for diversion ditches as well as for levees and road banks. In addition, there are some comparatively tall grasses that can be used with fair results for road banks. These are:

Malojilla, *Eriochloa polystachya*, H. B. K.
Molasses, *Melinis minutiflora*, Beauv.
Malojillo del monte, *Panicum laxum*, Swartz
Panicum adspersum, Trin.

Grasses Suitable for Controlling Sheet Erosion

This type of erosion wherein the surface layer of good soil is washed away by run-off water in a uniform sheet is one of the most destructive. It is noticed only when the soil is almost ruined, and the subsoil is beginning to appear at the surface. It can be checked in time by planting and sowing various highly stoloniferous grasses, with abundance of growth above ground to prevent the direct beating of the rain against the soil. Grasses should be chosen that will add considerable organic matter to the surface soil to increase its water absorbing capacity. They must be quick cover-forming grasses and possess an abundance of deep, netted roots at the main stems and at the nodes. And, in Puerto Rico they must necessarily be of some economical value. Puerto Rican grasses tested and found to have the required characteristics are given below:

Molasses, *Melinis minutiflora*, Beauv.
Para grass, *Panicum purpurascens*, Raddi.
Malojilla, *Eriochloa polystachya* (H. B. K.), Hitchc.
Pata de gallina, *Digitaria horizontalis*, Willd.
St. Augustine grass, *Stenotaphrum secundatum* (Walt.), Kuntze.
Sour grama, *Paspalum conjugatum*, Bergius.
Carpet grass, *Axonopus compressus* (Swartz), Beauv.
Malojillo del monte, *Panicum laxum*, Swartz.
Yerba de Madera, *Oplismenus hirtellus* (L.), Beauv.
Straw grass, *Andropogon annulatus*, Forsk.
Matojo de Playa, *Sporobolus virginicus* (L.), Kunth.
Palmilla, *Setaria palmifolia* (Willd.), Stapf.
Pata de gallina enana, *Digitaria sanguinalis* (L.), Scop.
River grass, *Echinochloa polystachya* (H. B. K.), Hitch.
Knotgrass, *Paspalum distichum*, L.
Hairy hen foot, *Digitaria villosa* (Walt.), Pers.
Bermuda grass, *Cynodon dactylon* (L.), Pers.
Melaillo, *Panicum glutinosum*, Swartz.
Pendejuelo, *Paspalum decumbens*, Swartz.
Arroz del monte, *Echinochloa colonum* (L.), Link.

Grasses Suitable for Pasture Revegetation

In Puerto Rico, most of the land devoted to pasture has been overgrazed for many years. As a result of this, sheet erosion, as well as gully erosion, has caused an impoverishment of such lands. Such lands and pastures should be furrowed on the contour and left to rest for a considerable period, and then reseeded or replanted to species of palatable native grasses that will serve the double purpose of checking erosion and providing forage or grazing. Native grasses adapted for such a use are here named:

Malojilla, *Eriochloa polystachya*, H. B. K.
Natal grass, *Tricholaena repens* (Willd.), Hitch.
Molasses grass, *Melinis minutiflora*, Beauv.
St. Augustine grass, *Stenotaphrum secundatum* (Walt.), Kuntze.
Carpet grass, *Axonopus compressus* (Swartz), Beauv.
Short finger grass, *Chloris inflata*, Link.
Hairy grass, *Paspalum paniculatum*, L.
Malojillo del monte, *Panicum laxum*, Swartz.
Yerba de deo, *Chloris petraea*, Swartz.
Melaillo, *Panicum glutinosum*, Swartz.
Yerba dulce, *Paspalum plicatulum*, Michx.
Matojo blanco, *Paspalum virgatum*, L.
Palmilla, *Setaria palmifolia* (Willd.), Stapf.
River grass, *Echinochloa polystachya* (H. B. K.), Hitchc.
Aquatic grass, *Panicum aquaticum*, Poir.
Trompetilla, *Hymenachne amplexicaulis* (Rudge), Nees.
Ricegrass, *Leersia hexandra*, Swartz.
Knotgrass, *Paspalum distichum*, L.
Yerba de agua, *Panicum geminatum*, Forsk.
Sour grama, *Paspalum conjugatum*, Bergius.
Lovegrass, *Eragrostis ciliaris* (L.), Link.
Pendejuelo, *Paspalum decumbens*, Swartz.
Cerrillo, *Sporobolus indicus* (L.), R. Br.
Grama de costa, *Chloris radiata* (L.), Swartz.
Guinea grass, *Panicum maximum*, Jacq.
Hatico grass, *Ixophorus unisetus* (Presl.), Schlecht.
Rabo de ardilla, *Setaria vulpisets* (Lam.), Roem, and Schult.
Straw grass, *Andropogon annulatus*, Forsk
Matojo de la arena, *Paspalum laxum*, Lam.
Yerba egipcia, *Dactyloctenium aegyptium* (L.), Richt.

Chemical analyses of these grasses are being made so that in revegetating an overgrazed field a combination of grasses may be formed according to the nutritive values of the species. A number of these grasses will be mixed and seeded in overgrazed pasture fields in combination with seeds of wild and cultivated legumes, and a sufficient rest period will be allowed in order to establish a permanent stand of grass vegetation.

A grazing plan designed to accomplish soil and water conservation, must be premised upon the proper use of those plant species which are being encouraged to grow and reproduce. Regardless of the proportion of these species to the total forage available, the rate of stocking must be based upon the amount of feed they supply, and management upon their particular requirements for growth and reproduction. In estimating the grazing capacity, all other species should be rated accordingly.

—*Liter E. Spence.*

III

Soils, Soil Conditions, and Their Relation to Erosion-Control Practices, Cayey Area

By Samuel Gracia

THE CAYEY AREA, as discussed in this paper, includes most of the municipalities of Cayey, Aibonito, and Cidra. These are in the central part of the island, in the Cordillera Central, a chain of mountains extending from the northeast to the southwestern part of Puerto Rico.

The area is well supplied with a network of insular roads connecting the three towns and extending to other parts of the island. There are also many municipal roads and trails which connect the towns with the rural zone.

The region is hilly and mountainous, with a few small valleys and terraces. The slope classes vary from 8 to 20 percent in the low relief soils, as the Toa, Mabí, and Torres, and from 20 to above 60 percent in the high relief soils as the Múcara, Jácana, Catalina, and Cialitos. The average slope for the last group of soils is around 50 percent.

The largest and most important river of the area is La Plata River, passing through Cayey, Cidra, and Aibonito, running north and flowing into the Atlantic Ocean. Most of the smaller rivers and brooks of the area are tributaries to La Plata. This region has a mild, cool climate most of the year. The average rainfall during the last 20 years has been approximately 56 inches.

Agriculture is the chief industry of the area. Tobacco and sugarcane are the leading crops with some coffee, pineapples, and minor crops in second place. Sugarcane is cultivated chiefly in the best soils of Cayey and Cidra. There are two planting seasons, one from January to May, known as spring planting, and the other from July to October, known as fall planting. Central Cayey grinds all the cane grown in the area. It is a small mill, having a grinding capacity of about 800 tons of cane per 24 hours. The grinding seasons last from January to May.

Tobacco is grown in the hilly and mountainous lands, with a few terraces and alluvial soils planted also. Growing season lasts from October to January. Such minor crops as beans and corn are planted after the tobacco is harvested. Múcara are the soils most used for tobacco growing.

General view of bank control experiment, showing terraces on the contour and grass plantings 2 months old. Bermuda grass in the center has developed much more rapidly than St. Augustine and centipede grasses on the left.

The principal soil series found in this area are Múcara, Catalina, Cialitos, Mabí, Jácana, Torres, and Toa.

Múcara soils are the most extensive of the area. They are derived from rocks of cretaceous age, most of which are igneous rocks predominantly andesitic. Múcara soils of this region, especially those devoted to tobacco, are usually shallow to rock. They are characterized by a dark grayish-brown to brown topsoil to an average depth of 6 to 8 inches. Intermingled with this layer is a high percentage of rock fragments. The surface soil does not usually rest on solid rock but passes by degrees through a broken mass of partly disintegrated rocks to the solid rock bed below. The depth of these soils varies from 4 to 8 inches on the ridge tops to 8 to 14 inches on the slopes.

Catalina soils in this region are found in the northeastern part of Cidra, in the eastern part of Cayey and in the central and northwestern part of Aibonito. Catalina soils are derived from andesitic tuffs. The topography ranges from rolling to steep, yet most of the hills are rounded with gently sloping ravines. The topsoil ranges from light red to reddish brown. The depth of the surface soil varies with surface relief. On the steeper, more eroded slopes, it does not average over 4 inches deep and when plowed some of the subsoil is tuned over. In the more rolling, less eroded areas, the surface is usually about 8 inches thick. The subsoil is a reddish-brown or light-red, slightly heavy, but friable clay. Roots penetrate it readily and water percolates rapidly, thus erosion in less severe than if

the soil were more plastic. At a depth of about 24 inches the soil becomes a deep red clay which is even more friable than the layer above but has less structure. This red clay continues to great depths and changes very little. Catalina soils in this region are devoted especially to sugarcane, pineapples, and minor crops, although some tobacco is grown in them.

Cialitos soils occur associated with Catalina. Topsoil ranges from light grayish brown to brownish red in color and passes into a yellowish-brown to light-brownish-red clay, having a slight tendency in places to have a mottled yellowish-brown and light brownish-red color. This shows that under drainage is not as good as in the Catalina soils, as they are not mottled. The depth to rock varies greatly in a short distance; in places it occurs at 30 inches while in other places it may be over 10 feet. In places the subsoil may be quite yellowish and have rock fragments through the profile area into the surface. In other areas the surface is very shallow due to sheet erosion. There are some sites where the reddish-brown subsoil may continue to a depth of 30 inches before the friable yellowish-red lower subsoil begins. Cialitos soils in this region have practically the same use as Catalina, when they are good Cialitos. Poor Cialitos are used for pasture.

Mabí soils are developed on low colluvial slopes or terrace-like positions of the Múcara soils. Mabí soils have a grayish-brown, in some cases almost black surface soil which is usually heavy and plastic when wet, but which works up into good tilth if handled properly. The surface soil is usually over 8 inches deep and quite fertile. On dry speels topsoil usually cracks. The subsoil is a yellowish-brown, plastic, heavy clay streaked moderately with rust yellow and brown. This layer gradually changes at a depth of 30 to 40 inches to a friable, brown and yellowish-brown silt loam which crumbles easily between the fingers. This grades into disintegrated rock material similar to that found under the Múcara soils. Fine, whitish specks of rock material occur in all layers. Mabí soils are slightly acid. The surface relief is smooth to slightly undulating. On the more level areas drainage is imperfect and is a difficult problem; even with ditches, water may become stagnated before it percolates through the deep, plastic, sticky clay subsoil.

Most of the Mabí soils of this area are devoted to tobacco and sugarcane. Plantains seem not to do very well on Mabí soils.

Torres soils occur on terrace positions very frequently adjacent to streams. The topsoil has a brownish-gray to brown surface about 8 inches deep, underlain by a light-red or reddish-brown, moderately fine silty clay streaked more or less with yellow which gradually changes to a friable reddish brown, and in places red gravelly loam or clay loam to a depth below 3 feet. In most places rounded gravel occurs throughout the profile. All layers are quite acid. Exposures indicate that the soil is stratified. There may be several gravelly layers in the deeper deposits, and in places they have undergone sufficient weathering to form layers similar to the Catalina clay.

Jácana soils may be considered as very deep Múcara soils. They are derived from tuff and occur on gradual slopes below Múcara soils and in its concave slopes. The topsoil has a dark-gray to brown color and varies from 6 inches to about 1 foot in thickness. This passes more or less gradually into the yellowish- or reddish-brown subsoil which in most cases consists of clayey material with a large quantity of sharply edged and partly rotten rubble. Jácana, Mabí, and Múcara are associated soils.

Toa soils are not abundant on this region. These soils have a brown to yellow-brown, well-oxidized soil material over a yellowish-brown alluvial subsoil. No heavy B horizon is present. Occasionally, slight mottling is found below 30 inches depth. Toa soils are usually very fertile, excepting the sandy types.

Sheet erosion is quite severe in this area. About 50 to 75 percent of topsoil has been removed. Múcara types are the most seriously eroded and in places barren rock is found in these soils. Catalina and Cialitos show considerable sheet erosion but not so deeply as the Múcara, Mabí, Jácana, Torres, and Toa which show less erosion due to their lower surface relief. The table shows the percentage of erosion found on the soils of La Plata Farm, Cayey area, Puerto Rico.

Soil series	Erosion class					Total acres
	0	2	3	33	4	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Acres*
Múcara	1.64	3.04	81.22	374.00	45.07	304.97
Mabí	5.73	7.66	126.94	29.28	.....	169.61
Jácana	.....	.....	22.30	14.41	.....	36.91
Toa	.....	2.51	.....	.....	.....	2.51
Total	7.37	13.21	230.66	417.69	45.07	714.00

More than 1 billion and 54 million acres of land in the United States is farm or ranch land owned by private landholders. This is more than four times as much as is included in Federal and State forests, parks, and game refuges, and is fully 55 percent of the land in the country.

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